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Depositional Environment and Geochemical Classification of Ilaro Sandstone, Dahomey Basin, Southwestern Nigeria

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Abstract

Sandstones are sedimentary rocks formed from cemented sand-sized clasts. The cement that binds the clasts can vary from clay minerals to ca, silica or iron oxides. Sandstone can be further divided according to: Clast size – fine (0.06-0.2mm), medium (0.2-0.6mm), coarse (0.6-2mm); Sorting - poorly sorted, moderately well sorted and well sorted. Sandstones could also be discussed in terms of little or significant amount of silt and / or clay as arenaceous or argillaceous (wacke). Nine (9) samples were collected from the Ilaro sandstone and subjected to granulometric, petrographic and geochemical analysis precisely ICP-MS (Inductively coupled plasma mass spectrometry) for the major elements and their oxides. Granulometric analysis reveals that the texture of the sediments ranged from medium to coarse through to very coarse, they are symmetrically skewed and dominantly mesokurtic. Bivariate plot however depicts the Ilaro sandstone to be fluvatile in their depo-setting. All the samples also showed strong inclination towards sub-greywacke in terms of their geochemical classification.

Keyword: granulometric; mesokurtic; fluvatile; sub-greywacke; sandstone.

1. Introduction

The Ilaro sandstone conformably overlies the Oshosun Formation and it consists of massive, yellowish, poorly consolidated, fine to coarse, cross-bedded sandstones with thin clays and shales.

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It is part of the Dahomey basin and of Eocene age. Sandstone, sometimes known as arenite, is a clastic sedimentary rock comprised of sand-sized minerals or rock grains. Most sandstone is composed of quartz and/or feldspar because these are the most common minerals in the earth's crust. Like sand, sandstone can be any color but the most common colors are tan, brown, yellow, red, grey, pink, white and black. Rock formations that are primarily composed of sandstone usually allow percolation of water and other fluids and are porous enough to store large quantities, making them valuable aquifers and petroleum reservoirs. Sandstones are clastic in origin (as opposed to either organic, like chalk and coal or chemical like gypsum and jasper). They are formed from cemented grains that may either be fragments of a pre-existing rock or be mono-mineralic crystals. The cement binding these grains together is typically calcite, clays and silica. The formation of sandstone involves two principal stages: First, a layer or layers of sand accumulate as a result of sedimentation, either from water (stream, lake and sea) or from air (as in a desert). The environment where the sandstone is deposited is crucial in determining the characteristics of the resulting sandstone, which, in finer detail, include its grain size, sorting, and composition and, in more general detail, include the rock geometry and sedimentary structures. Principal environments of deposition may be split between terrestrial and marine as illustrated by the following broad groupings:

1.1 Terrestrial Environment

- Rivers (levees, point bars, channel sands), Alluvial fans, Glacial outwash, Lakes, Deserts (sand dunes and ergs)

1.2 Marine Environments

- Deltas, Beach and shoreface sand, Tidal flats, Offshore bars and sand waves, Storm deposits (tempestites). Turbidites (submarine channels and fans). Generally, the study area is on a relief of 200m above sea level and lies between latitude $6^{\circ}50'$ and $6^{\circ}57'N$ and longitude $2^{\circ}58'$ and $3^{\circ}05'E$. The formation falls around Kajola Abalabi in Ilaro south western part of Nigeria. Fig.2 The study area is accessible through Papalanto-Ifo road towards Ilaro town. It is also accessible by a major road, minor roads and several footpaths. The formation is exposed as a massive road cut.

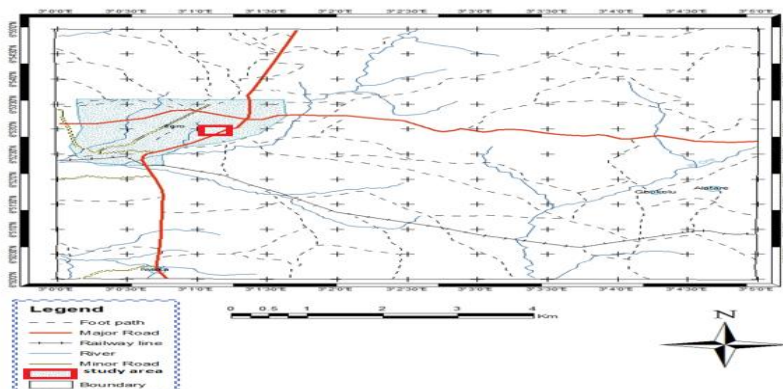


Figure 1: Drainage and accessibility map of the study area

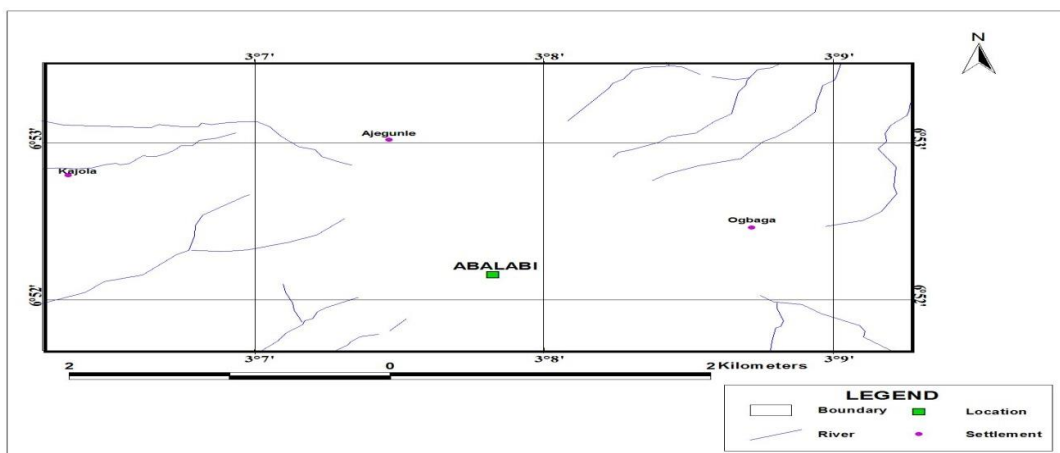


Figure 2: Location of the study Area.

This research paper aims at unraveling the depositional setting using granulometric analysis as well as further classifying the Ilaro sandstone based on result of geochemical analysis.

2. Materials and Method

The study area was traversed by foot and detailed geological mapping of the exposed sandstone was carried out. The co-ordinate and elevation of the outcrop above sea level were first recorded with the aid of a G.P.S (Global positioning System). Visually observable features were carefully mapped and recorded accordingly. These include color, texture, lithological unit, bedding pattern, presence of ichno fossils, visible minerals as well as intensity of weathering. strikes and dips readings were taken along the bedding planes of each litho-unit with the aid of compass clinometers to determine the trending pattern of the road-cut exposure. The entire road-cut exposure was logged and the thickness of each litho-unit was recorded. Nine samples were later collected from different litho-unit into sample bags and labeled with the use of a masking tape accordingly as L1 to L9 for ease of identification. The samples were then subjected to granulometric, petrographic and geochemical analysis. For granulometric analysis, initial weight of 50g of slightly pulverized sample was used, which was run through sieve openings of graded diameter (μm). Thin sections were also made for samples L1 to L9 and then viewed under petrologic microscope in both plane polarized light and under crossed nicol for mineral identification and modal composition of the inherent minerals in the Ilaro Sandstone. Photomicrographs of all the slides were then shot in both plane polarized light and under crossed nicol. Geochemical analysis was resolved using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) about 25g of each sample were pulverized into powdery form and major, trace and rare earth elements were analysed for, although the major elemental oxides were employed for geochemical calculations. Criteria for the classification of sandstones were further employed in classifying the Ilaro sandstone [1].

3. Literature Review

Authors in [2] Worked on the geochemistry and mineralogy of the Imobi sandstones. The study was aimed at inferring the provenance and possible depositional environment for these sandstones. Eight rock samples

The general sequence for the rock unit from the top are the Coastal plain sands, Ilaro formation, Oshosun formation, Akinbo formation, Ewekoro formation, and Abeokuta formation lying on the South western Basement Complex of Nigeria. The Dahomey basin is an extensive sedimentary basin in the Gulf of Guinea. It extends from south-eastern Ghana through Togo and Benin Republic on the west side to the Okitipupa ridge/Benin Hinge line on the west of Niger Delta

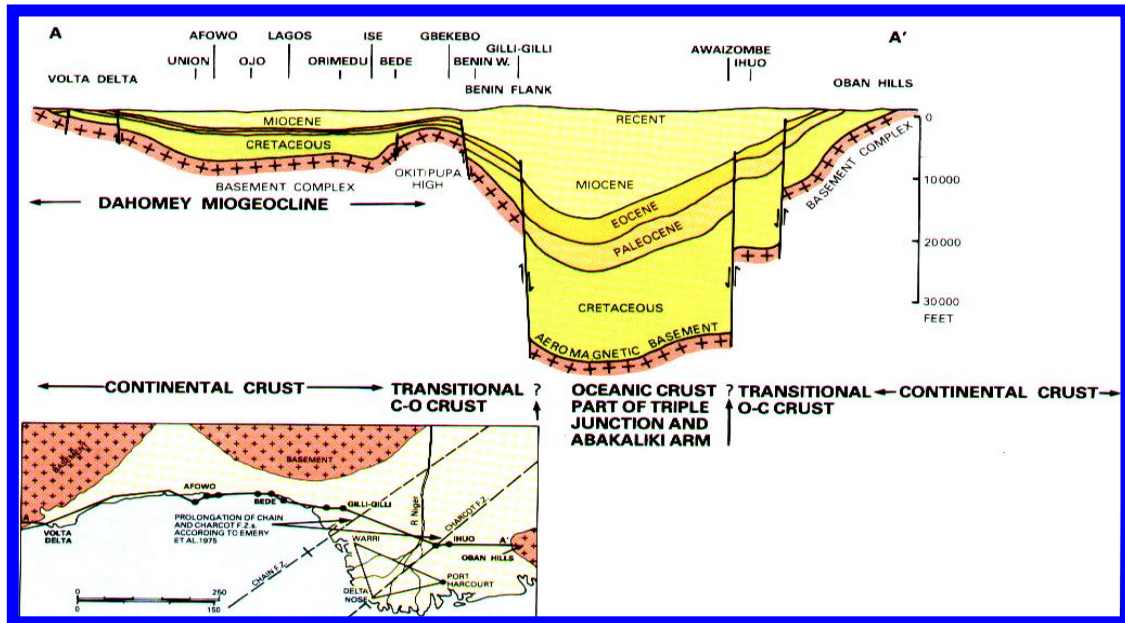


Figure 4: East-West Geological Section Showing the Dahomey (Benin) Basin and Niger Delta [7]

5. Results and Discussion

Table 1: Result of Sieve Analysis that shows Cumulative weight percent for samples L1-L9

Class(mm)	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%	Cumm Wt%
	IL1	IL2	IL3	IL4	IL5	IL6	IL7	IL8	IL9
2	1.7	0.42	14.88	5.14	5.1	13.18	15.98	6.14	14.96
1	17.76	0.8	50.61	18.66	17.9	34.84	51.66	34.04	37.00
0.71	36.16	17.79	64.25	33.03	28.3	40.7	65.56	49.64	49.26
0.5	60.48	29.51	75.2	53.19	45.74	58.1	76.56	66.18	64.44
0.355	79.5	45.4	82.44	68.67	65.16	68.26	83.82	78.94	77.54
0.25	88.38	63.4	88.22	81.1	81.48	78.2	89.22	88.4	87.52
0.18	92.26	77.83	92.36	89.26	90.3	86.26	93.16	94.08	93.96
0.125	95.56	91	96.08	95.06	95.8	93.74	96.68	97.16	97.5
0.075	100	100	100	100	100	100	100	100	100

Table 2: Result of Sieve Analysis that shows weight percent for samples L1-L9

Interval Phi(ϕ)	Wt% IL1	Wt% IL2	Wt% IL3	Wt% IL4	Wt% IL5	Wt% IL6	Wt% IL7	Wt% IL8	Wt% IL9
-1.0	1.7	0.42	14.88	5.15	5.1	13.18	15.98	6.14	14.96
0.0	16.07	8.37	35.74	13.52	12.8	21.16	35.68	27.9	22.04
0.5	18.4	9.00	13.64	14.38	10.4	10.36	13.9	15.6	12.26
1.00	24.31	11.72	10.95	20.17	17.44	13.4	11.0	16.54	15.18
1.5	19.03	15.91	7.23	15.45	19.42	10.16	7.26	12.76	13.1
2.0	8.88	18.00	5.79	12.45	16.32	9.94	5.4	9.46	9.98
2.5	4.23	14.44	4.13	8.15	8.82	8.42	3.94	5.68	6.44
3.0	2.96	13.19	3.72	5.79	5.5	5.5	3.52	3.08	3.54
3.5	4.44	9.00	3.93	4.94	4.2	4.2	3.32	2.84	2.5

For calculating grain-size statistical parameters by graphical method, [8] mathematical expressions were adopted and Percentile values were then extrapolated.

Table 3: Percentile Values for Samples L1 - L9

Percentiles	L1	L2	L3	L4	L5	L6	L7	L8	L9
5	-0.4	-0.6	-1.5	-1.18	-1	-1.7	-1.65	-1.1	-1.7
16	-0.1	0.4	-0.8	-0.2	-0.1	-0.75	-1	-0.6	-0.8
25	0.2	0.8	-0.5	0.2	0.3	-0.3	-0.65	-0.2	-0.4
50	0.8	1.6	-0.1	0.9	1.1	0.6	0	0.5	0.5
75	1.4	2.5	1.3	1.8	2.1	1.9	1	1.3	1.4
84	1.8	2.75	2	2.5	2.3	2.2	1.5	1.7	1.8
95	3	3.3	3	3	2.8	3	2.7	2.78	2.5

Table 4: Sieve Analysis Table for samples L1 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	0.68	0.85	0.85	1.7	1.7
1	0	7.6	8.03	8.88	17.76	16.07
0.71	0.5	8.7	9.2	18.08	36.16	18.4
0.5	1	11.5	12.16	30.24	60.48	24.31
0.355	1.5	9	9.51	39.75	79.5	19.03
0.25	2	4.2	4.44	44.19	88.38	8.88
0.18	2.5	2	2.11	46.3	92.26	4.23
0.125	3	1.4	1.48	47.78	95.56	2.96
0.075	3.75	2.1	2.22	50	100	4.44
Receiving pan		2.1				
Total		47.3	50			100.02
Weight loss		2.7				

Table 5: Sieve Analysis Table for samples L2 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	0.2	0.21	0.21	0.42	0.42
1	0	4	4.19	4.4	0.8	8.37
0.71	0.5	4.3	4.5	8.9	17.79	9
0.5	1	5.6	5.86	14.76	29.51	11.72
0.355	1.5	7.6	7.95	22.71	45.4	15.91
0.25	2	8.6	9	31.71	63.4	18
0.18	2.5	6.9	7.22	38.93	77.83	14.44
0.125	3	6.3	6.59	45.52	91	13.19
0.075	3.75	4.3	4.5	50.02	100	9
Receiving pan		1.4				
Total		47.78	50.02			100.05
Weight loss		2.22				

Rt-Retained Wt-Weight

Table 6: Sieve Analysis Table for samples L3 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	7.2	7.44	7.44	14.88	14.88
1	0	17.3	17.87	25.31	50.61	35.74
0.71	0.5	6.6	6.82	32.13	64.25	13.64
0.5	1	5.3	5.48	37.61	75.2	10.95
0.355	1.5	3.5	3.62	41.23	82.44	7.23
0.25	2	2.8	2.89	44.12	88.22	5.79
0.18	2.5	2	2.07	46.19	92.36	4.13
0.125	3	1.8	1.86	48.05	96.08	3.72
0.075	3.75	1.9	1.96	50.01	100	3.93
Receiving pan		1.3				
Total		48.4	50.01			100
Weight loss		1.6				

Table 7: Sieve Analysis Table for samples L4 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight(gm)	Cumulative weight (gm)	Cumulative weight in %	Weight in %
2	-1	2.4	2.57	2.57	5.14	5.15
1	0	6.3	6.76	9.33	18.66	13.52
0.71	0.5	6.7	7.19	16.52	33.03	14.38
0.5	1	9.4	10.09	26.61	53.19	20.17
0.355	1.5	7.2	7.73	34.34	68.67	15.45
0.25	2	5.8	6.22	40.56	81.1	12.45
0.18	2.5	3.8	4.08	44.64	89.26	8.15
0.125	3	2.7	2.9	47.54	95.06	5.79
0.075	3.75	2.3	2.47	50.01	100	4.94
Receiving pan		2.5				
Total		46.6	50.01			100
Weight loss		3.4				

Rt-Retained Wt-Weight

Table 8: Sieve Analysis Table for samples L5 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight(gm)	Cumulative weight (gm)	Cumulative weight in %	Weight in %
2	-1	2.4	2.57	2.57	5.14	5.15
1	0	6.3	6.76	9.33	18.66	13.52
0.71	0.5	6.7	7.19	16.52	33.03	14.38
0.5	1	9.4	10.09	26.61	53.19	20.17
0.355	1.5	7.2	7.73	34.34	68.67	15.45
0.25	2	5.8	6.22	40.56	81.1	12.45
0.18	2.5	3.8	4.08	44.64	89.26	8.15
0.125	3	2.7	2.9	47.54	95.06	5.79
0.075	3.75	2.3	2.47	50.01	100	4.94
Receiving pan		2.5				
Total		46.6	50.01			100
Weight loss		3.4				

Table 9: Sieve Analysis Table for samples L6 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	6.1	6.59	6.59	13.18	13.18
1	0	9.8	10.58	17.17	34.84	21.16
0.71	0.5	4.8	5.18	22.35	40.7	10.36
0.5	1	6.2	6.7	29.05	58.1	13.4
0.355	1.5	4.7	5.08	34.13	68.26	10.16
0.25	2	4.6	4.97	39.1	78.2	9.94
0.18	2.5	3.9	4.21	43.31	86.26	8.42
0.125	3	3.3	3.56	46.87	93.74	7.12
0.075	3.5	2.9	3.13	50	100	6.26
		Total	=	Total = 50		100
		46.30				
Weight Retained in Pan =3.5g						
Weight loss = 0.2g						

Rt-Retained Wt-Weight

Table 10: Sieve Analysis Table for samples L7 (Initial Weight of sample = 50)

Class MM	Interval phi ϕ	Rt. wt)	Corrected wt. (gm)	Cumm wt.(gm)	Cumulative wt. in %	Weight in %
-1		7.7		15.98	15.98	
2	0	17.2	17.84	25.83	51.66	35.68
1	0.5	6.7	6.95	32.78	65.56	13.9
0.71	1	5.3	5.5	38.28	76.56	11
0.5	1.5	3.5	3.63	41.91	83.82	7.26
0.355	2	2.6	2.7	44.61	89.22	5.4
0.25	2.5	1.9	1.97	46.58	93.16	3.94
0.18	3	1.7	1.76	48.34	96.68	3.52
0.125	0.075	3.5	1.6	1.66	50	100
Weight pan =1.8g	rt,in	Total=	Total = 50			Total =
Weight =0g	loss	48.20				100

Table 11: Sieve Analysis Table for samples L8 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	2.6	3.07	3.07	6.14	6.14
1	0	11.8	13.95	17.02	34.04	27.9
0.71	0.5	6.6	7.8	24.82	49.64	15.6
0.5	1	7	8.27	33.09	66.18	16.54
0.355	1.5	5.4	6.38	39.47	78.94	12.76
0.25	2	4	4.73	44.2	88.4	9.46
0.18	2.5	2.4	2.84	47.04	94.08	5.68
0.125	3	1.3	1.54	48.58	97.16	3.08
0.075	3.5	1.2	1.42	50	100	2.84
		Total	=	Total = 50		Total =
		42.30				100
Weight Retained in Pan =1.3g						
Weight loss = 6.4g						

Rt-Retained Wt-Weight

Table 12: Sieve Analysis Table for samples L9 (Initial Weight of sample = 50g)

Sieve size	Phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	7.2	7.48	7.48	14.96	14.96
1	0	10.6	11.02	18.5	37	22.04
0.71	0.5	5.9	6.13	24.63	49.26	12.26
0.5	1	7.3	7.59	32.22	64.44	15.18
0.355	1.5	6.3	6.55	38.77	77.54	13.1
0.25	2	4.8	4.99	43.76	87.52	9.98
0.18	2.5	3.1	3.22	46.98	93.96	6.44
0.125	3	1.7	1.77	48.75	97.5	3.54
0.075	3.5	1.2	1.25	50	100	2.5
		Total	=	Total = 50		Total =
		48.10				100
Weight Retained in Pan =1.5g						
Weight loss = 0.4g						

Rt-Retained Wt-Weight



Figure 5: picture showing logging of a sandstone litho-unit

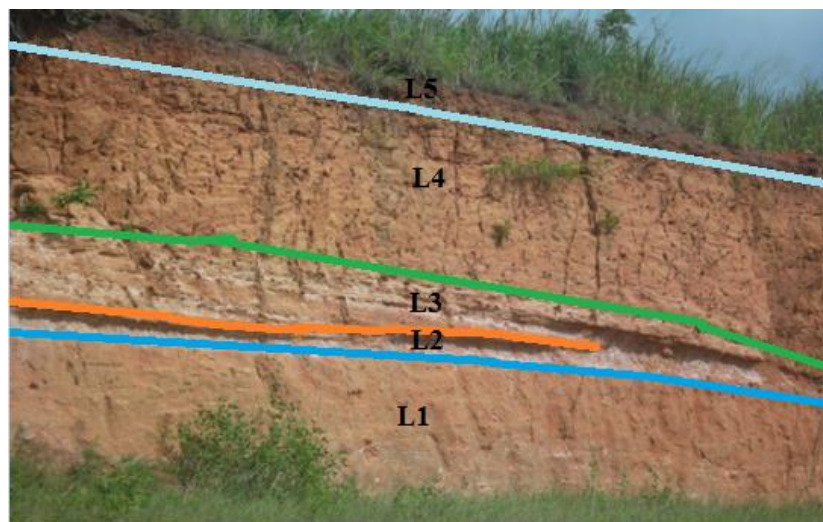


Figure 6: Delineation of the Ilaro Sandstone into different Lithology

Table 13: Derived Values of Grain Size Statistical Parameters for Samples L1-L9

Sample no	Graphic mean(M_z)	Dispersion sorting(σ)	Graphic skewness(SK_t)	Graphic kurtosis(K_G)
L1	0.83	1	0.17	1.17
L2	1.58	1.2	-0.08	0.94
L3	0.37	1.38	0.52	1.03
L4	1.07	1.31	0.11	1.07
L5	1.1	1.7	-0.053	0.87
L6	2.05	1.45	0.0529	0.8
L7	0.17	1.28	0.22	1.08
L8	0.53	1.16	0.11	1.06
L9	0.5	1.29	-0.22	0.96

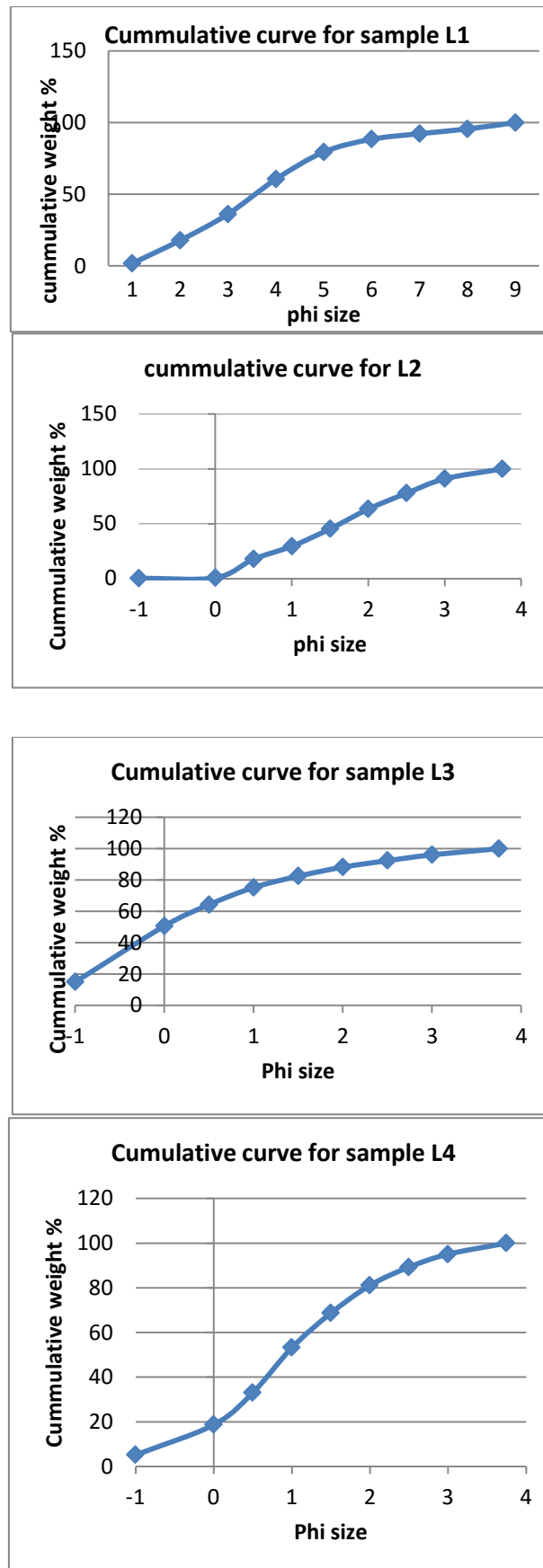


Figure 7: Plot of Cumulative frequency against phi size for samples L1-L4

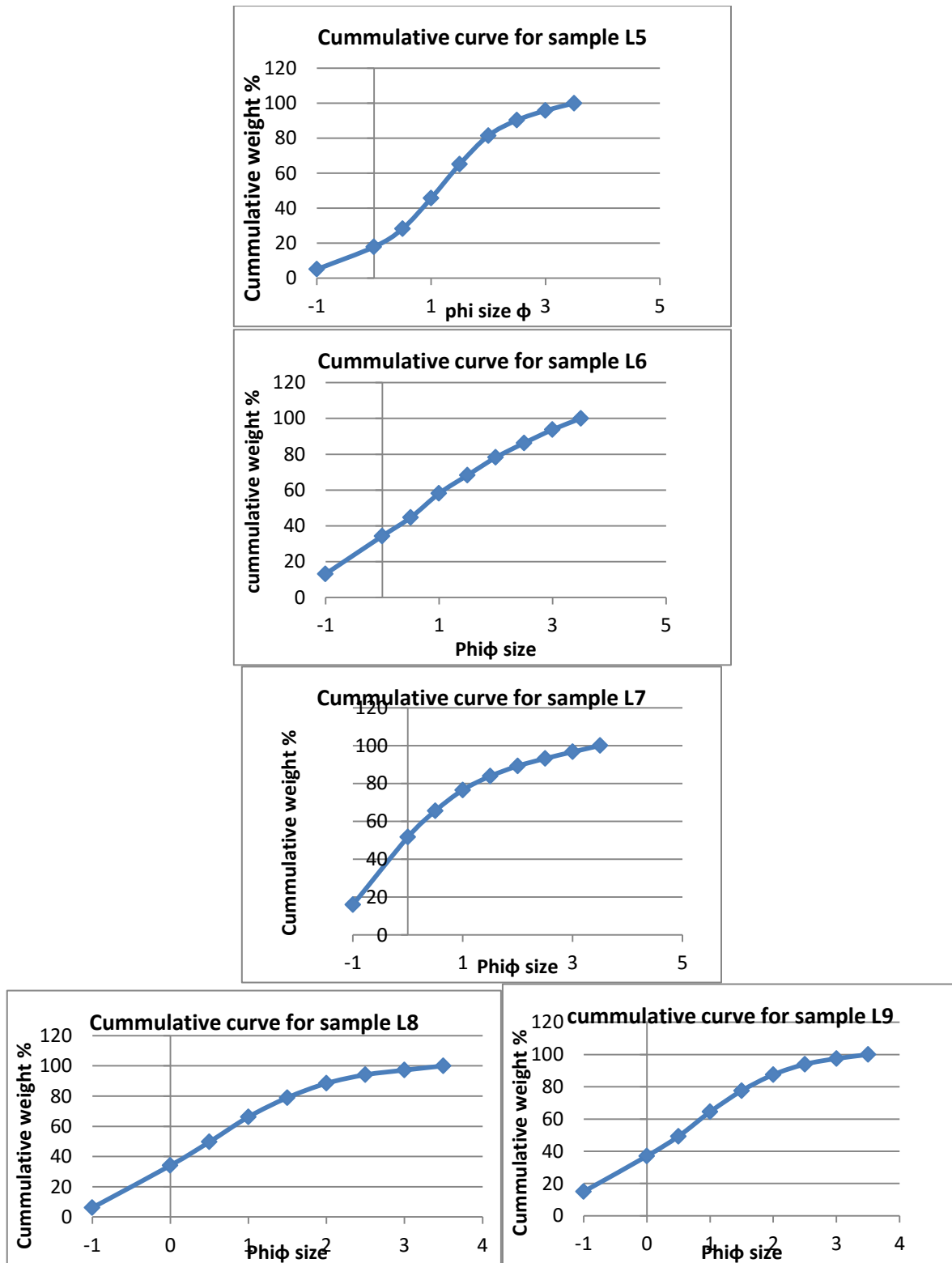


Figure 8: Plot of Cumulative frequency against phi size for samples L5-L9

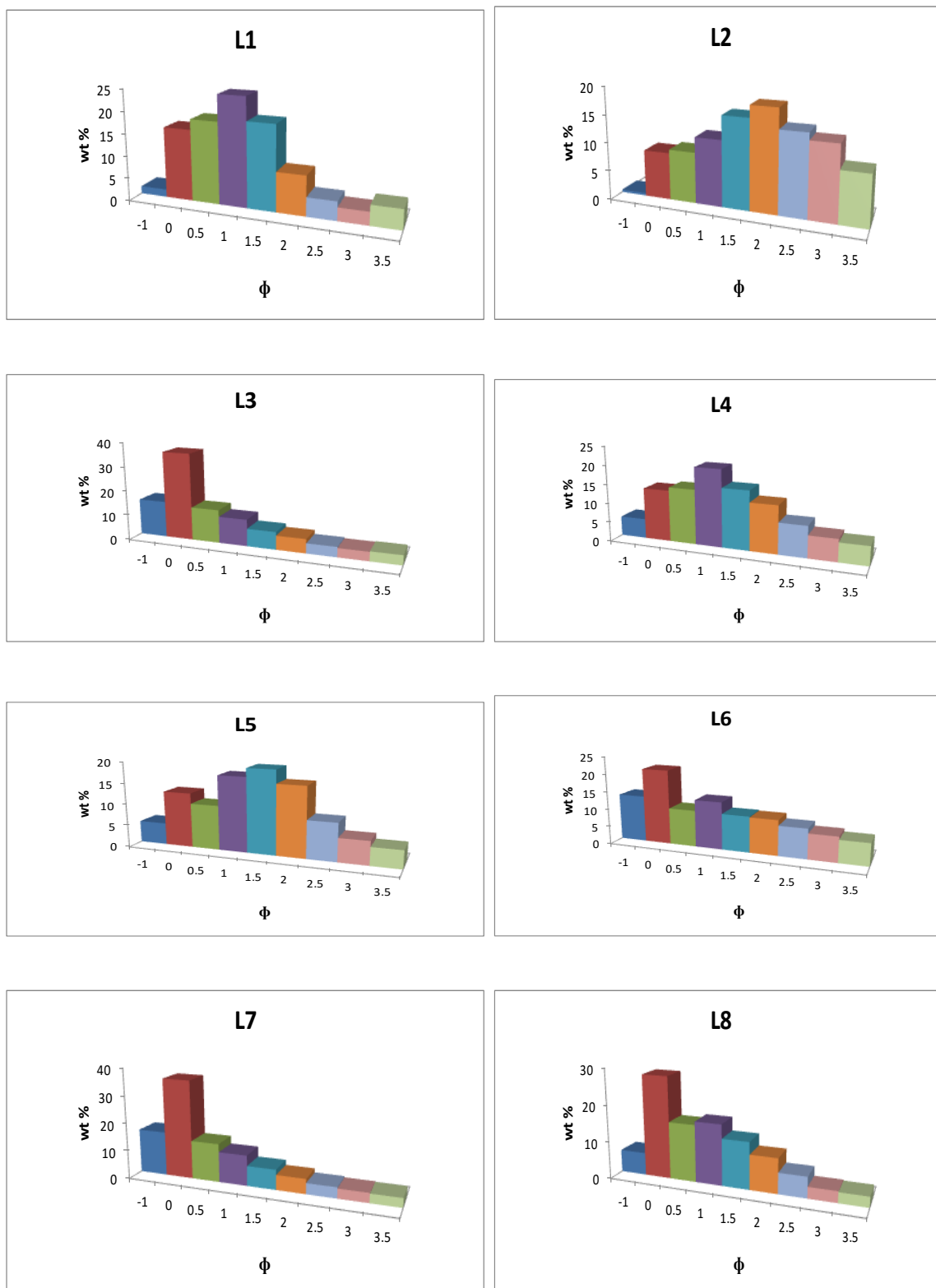


Figure 9a: Histogram showing modal variations

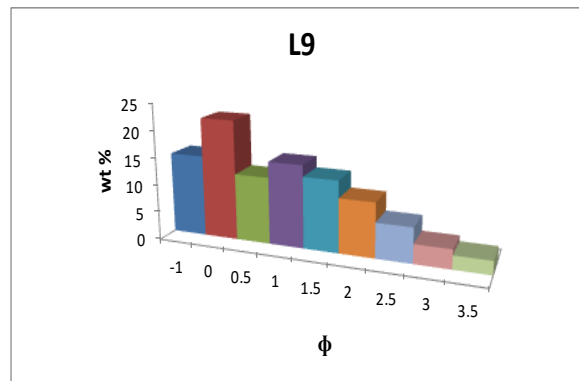


Figure 9b: Histogram showing modal variations

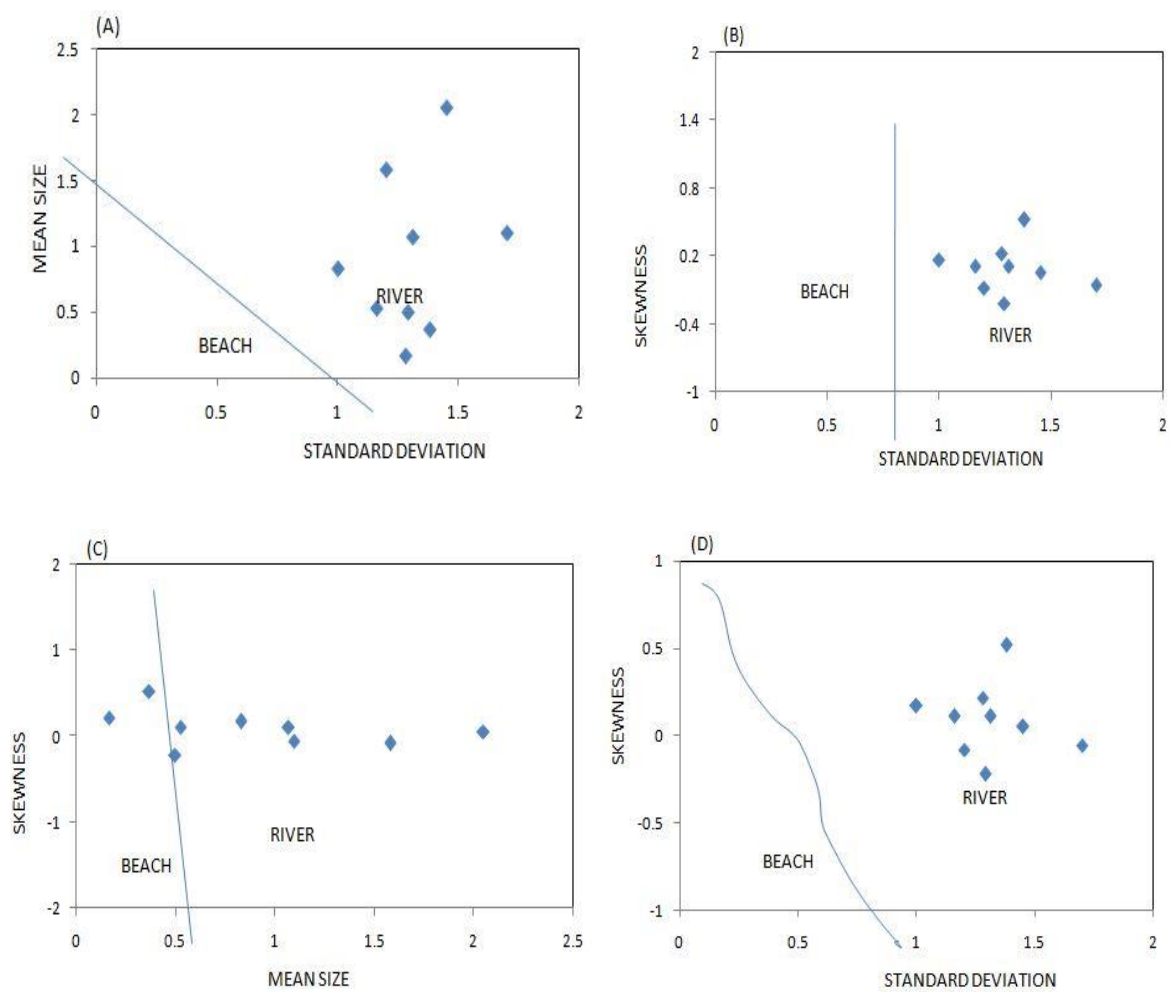


Figure 10: Bivariate plots depicting depositional setting

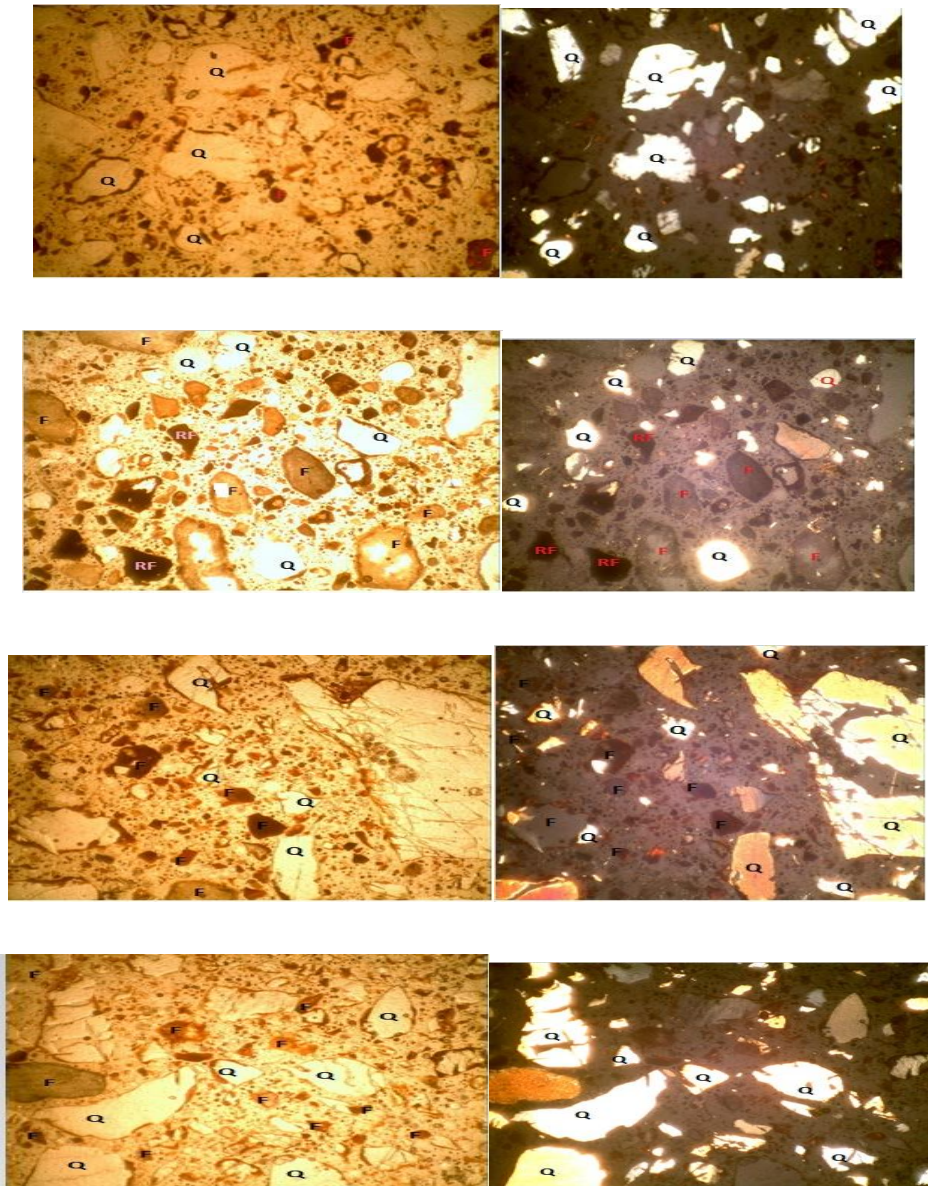
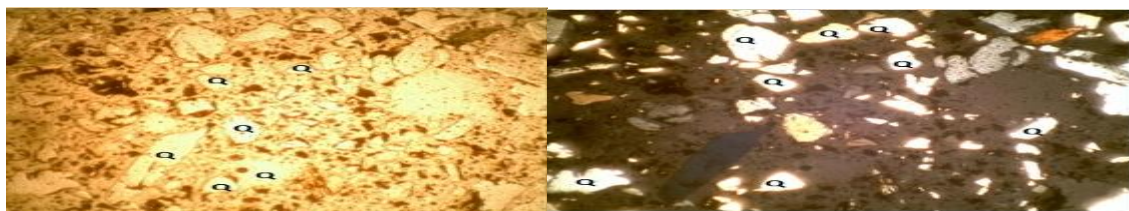


Figure 11: Photomicrographs of the Ilaro sandstone in plane polarized light and under crossed nicols.



----- Bar Scale = 20mm Magnification: X40 Resolution: (1.50 dpi)

Figure 12: Photomicrographs of the Ilaro sandstone in plane polarized light and under crossed nicols.

Table 14: Average modal analysis of the Sandstone Samples

SAMPLE NO	QUARTZ	FELDSPAR	RUTILE	GARNET	TOURMALINE	ROCK FRAGMENT
2L1	80	10	2	1	2	3
2L2	70	25	2	-	-	3
2L3	70	25	2	1	-	2
2L4	92	1	2	1	2	2
2L5	80	4	2	2	2	10

Table 15: Geochemical result for samples L1 - L9

	Sample location 1	Sample location 2	Sample location 3	Sample location 4	Sample location 5	Sample location 6	Sample location 7	Sample location 8	Sample location 9
SiO ₂	86.8	56.64	87.41	80.94	83.15	53.9	81.66	86.85	80.57
Al ₂ O ₃	7.38	27.67	7.31	10.68	9.63	28.46	11.76	7.93	7
³ Fe ₂ O ₃	1.56	2.43	1.22	2.71	2.27	3.71	1.03	1.24	6.79
³ MgO	0.02	0.05	0.02	0.04	0.03	0.05	0.02	0.02	0.05
CaO	0.009	0.01	0.01	0.04	0.009	0.009	0.009	0.009	0.08
Na ₂ O	0.008	0.02	0.006	0.007	0.009	0.02	0.009	0.009	0.01
K ₂ O	0.02	0.16	0.03	0.03	0.03	0.18	0.05	0.02	0.03
TiO ₂	0.4	1.37	0.33	0.57	0.72	1.57	0.45	0.35	0.54
P ₂ O ₅	0.02	0.03	0.22	0.03	0.02	0.05	0.01	0.01	0.05
MnO	0.005	0.01	0.04	0.003	0.009	0.01	0.009	0.009	0.04
Cr ₂ O ₃	0.004	0.0015	0.09	0.009	0.005	0.016	0.004	0.004	0.016
³ Sum	96.29	88.39	96.57	95.059	95.93	87.98	95.01	96.45	95.18

The following are the parameter for the classification of sandstones based on chemical approach. They are used according to [9]

- 1) Quartz arenite: $\log (\text{SiO}_2/\text{Al}_2\text{O}_3) \geq 1.5$
- 2) Greywacke: $\log (\text{SiO}_2/\text{Al}_2\text{O}_3) < 1$ and $\log (\text{K}_2\text{O}/\text{Na}_2\text{O}) < 0$
- 3) Arkose (includes subarkose): $\log (\text{SiO}_2/\text{Al}_2\text{O}_3) < 1.5$ and $\log (\text{K}_2\text{O}/\text{Na}_2\text{O}) \geq 0$ and $\log ((\text{Fe}_2\text{O}_3+\text{MgO})/(\text{K}_2\text{O}+\text{Na}_2\text{O})) < 0$
- 4) Lithic arenite (subgraywacke, includes protoquartzite): $\log (\text{SiO}_2/\text{Al}_2\text{O}_3) < 1.5$ and either $\log (\text{K}_2\text{O}/\text{Na}_2\text{O}) < 0$ or $\log ((\text{Fe}_2\text{O}_3+\text{MgO})/(\text{K}_2\text{O}+\text{Na}_2\text{O})) \geq 0$. If $\log (\text{K}_2\text{O}/\text{Na}_2\text{O}) < 0$, lithic arenite can be confused with graywacke. The coastal plain sediments fall within the requirements of the third condition and thus classified as an arkose (includes subarkose).

Table 17

Sample L₁	Sample L₂
SiO ₂ = 86.86	Si O ₂ = 56.64
Al ₂ O ₃ = 7.38	Al ₂ O ₃ = 27.67
Log SiO ₂ / Al ₂ O ₃ = log (86.86 / 7.38)	Log SiO ₂ / Al ₂ O ₃ = log (56.64 / 27.67)
Log 11.77 = 1.07	Log (2.05) = 0.31
K ₂ O = 0.02	K ₂ O = 0.16
Na ₂ O = 0.008	Na ₂ O = 0.02
Log (K ₂ O/Na ₂ O) = log (0.02) – Log (0.008)	Log (K ₂ O/Na ₂ O) = log (K ₂ O) – log (Na ₂ O)
Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O)	= log (0.16) – log (0.02)
Fe ₂ O ₃ = 1.56	= -0.8 – (-1.7)
MgO = 0.02	= 0.9
Na ₂ O = 0.008	Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O)
K ₂ O = 0.02	Fe ₂ O ₃ = 2.43
Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O) = log (1.56+ 0.02) / (0.008 + 0.02)	MgO = 0.05
Log (1.58) / (0.028) = log (56.42) = 1.75	Na ₂ O = 0.02
	K ₂ O = 0.16
	Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O) = log (2.43+ 0.05) / (0.02 + 0.16)
	= log (2.48) / (0.18)
Log (1.24) / (0.036) = log (34.44) = 1.54	= log (13.78) = 1.14

Table 18

Sample L₃	Sample L₄
SiO ₂ = 87.41	Log SiO ₂ / Al ₂ O ₃
Al ₂ O ₃ = 7.31	SiO ₂ = 80.94
Log SiO ₂ / Al ₂ O ₃ = log (87.41 / 7.31)	Al ₂ O ₃ = 10.68
Log (11.96) = 1.08	Log SiO ₂ / Al ₂ O ₃ = log (80.94 / 10.68)
Log (K ₂ O/Na ₂ O)	Log (7.58) = 0.9
K ₂ O = 0.03	Log (K ₂ O/Na ₂ O)
Na ₂ O = 0.006	K ₂ O = 0.03
Log (K ₂ O/Na ₂ O) = log (0.03) – log (0.006)	Na ₂ O = 0.007

$= -1.52 - (-2.22)$	$\text{Log (K}_2\text{O/Na}_2\text{O)} = \text{log (K}_2\text{O)} - \text{log (Na}_2\text{O)}$
$= -1.52 + 2.22$	$\text{Log (0.03)} - \text{log (0.007)} = -1.52 - (-2.15)$
0.7	0.63
$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O})$	0.63
$\text{Fe}_2\text{O}_3 = 1.22$	$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O})$
	$\text{Fe}_2\text{O}_3 = 2.71$
$\text{MgO} = 0.02$	$\text{MgO} = 0.04$
$\text{K}_2\text{O} = 0.03$	$\text{Na}_2\text{O} = 0.007$
	$\text{K}_2\text{O} = 0.03$
$\text{Na}_2\text{O} = 0.006$	$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O}) = \text{log (2.71 + 0.04)} / (0.007 + 0.03)$
$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O}) =$ $\text{log (1.22 + 0.02)} / (0.03 + 0.006)$	$\text{Log (2.75 / 0.037)} = \text{log (74.52)} = 1.87$

Table 19

Sample L₅	Sample L₆
$\text{Log SiO}_2 / \text{Al}_2\text{O}_3$	$\text{Log SiO}_2 / \text{Al}_2\text{O}_3$
$\text{SiO}_2 = 83.15$	$\text{SiO}_2 = 53.90$
$\text{Al}_2\text{O}_3 = 9.63$	$\text{Al}_2\text{O}_3 = 28.46$
$\text{Log SiO}_2 / \text{Al}_2\text{O}_3 = \text{log (83.15 / 9.63)}$	$\text{Log SiO}_2 / \text{Al}_2\text{O}_3 = \text{log (53.90 / 28.46)}$
$\text{Log (8.63)} = 0.93$	$\text{Log (1.89)} = 0.28$
$\text{Log (K}_2\text{O/Na}_2\text{O)}$	$\text{Log (K}_2\text{O/Na}_2\text{O)}$
$\text{K}_2\text{O} = 0.03$	$\text{K}_2\text{O} = 0.18$
$\text{Na}_2\text{O} = 0.009$	$\text{Na}_2\text{O} = 0.02$
$\text{Log (K}_2\text{O/Na}_2\text{O)} = \text{log (K}_2\text{O)} - \text{log (Na}_2\text{O)}$	$\text{Log (K}_2\text{O/Na}_2\text{O)} = \text{log (K}_2\text{O)} - \text{log (Na}_2\text{O)}$
$\text{Log (0.03)} - \text{log (0.009)} = -1.52 - (-2.05)$	$\text{Log (0.18)} - \text{log (0.02)} = -0.74 - (-1.70)$
0.53	0.96
0.53	0.96
$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O})$	$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O})$
$\text{Fe}_2\text{O}_3 = 2.27$	$\text{Fe}_2\text{O}_3 = 3.71$
$\text{MgO} = 0.003$	$\text{MgO} = 0.05$
$\text{Na}_2\text{O} = 0.009$	$\text{Na}_2\text{O} = 0.02$
$\text{K}_2\text{O} = 0.03$	$\text{K}_2\text{O} = 0.18$
$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O}) = \text{log (2.27 + 0.003)}$ $/ (0.009 + 0.03)$	$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O}) = \text{log (3.71 + 0.05)}$ $/ (0.02 + 0.18)$
$\text{Log (2.273 / 0.039)} = \text{log (74.52)} = 1.77$	$\text{Log (3.76 / 0.20)} = \text{log (18.80)} =$

Table 20

Sample L₇	Sample L₈
Log SiO ₂ / Al ₂ O ₃	Log SiO ₂ / Al ₂ O ₃
SiO ₂ = 81.66	SiO ₂ = 86.85
Al ₂ O ₃ = 11.76	Al ₂ O ₃ = 7.93
Log SiO ₂ / Al ₂ O ₃ = log (81.66 / 11.76)	Log SiO ₂ / Al ₂ O ₃ = log (86.85 / 7.93)
Log (7.58) = 0.84	Log (10.95) = 1.04
Log (K ₂ O/Na ₂ O)	Log (K ₂ O/Na ₂ O)
K ₂ O = 0.05	K ₂ O = 0.02
Na ₂ O = 0.009	Na ₂ O = 0.009
Log (K ₂ O/Na ₂ O) = log (K ₂ O) – log (Na ₂ O)	Log (K ₂ O/Na ₂ O) = log (K ₂ O) – log (Na ₂ O)
Log (0.05) – log (0.009) = - 1.30 – (- 2.05)	Log (0.02) – log (0.009) = - 1.52 – (- 2.05)
0.75	0.53
0.75	0.53
Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O)	Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O)
Fe ₂ O ₃ = 1.03	Fe ₂ O ₃ = 1.24
MgO = 0.02	MgO = 0.02
Na ₂ O = 0.009	Na ₂ O = 0.009
K ₂ O = 0.05	K ₂ O = 0.02
Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O) = log (1.03 + 0.02) / (0.009 + 0.05)	Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O) = log (1.24 + 0.02) / (0.009 + 0.02)
Log (1.05 / 0.059) = log (17.80) = 1.25	Log (1.26 / 0.029) = log (43.44) = 1.64

Table 21

Sample L₉
Log SiO ₂ / Al ₂ O ₃
SiO ₂ = 80.57
Al ₂ O ₃ = 7.00
Log SiO ₂ / Al ₂ O ₃ = log (80.57 / 7.00)
Log (11.51) = 1.06
Log (K ₂ O/Na ₂ O)
K ₂ O = 0.03
Na ₂ O = 0.01

$$\text{Log (K}_2\text{O/Na}_2\text{O)} = \text{log (K}_2\text{O)} - \text{log (Na}_2\text{O)}$$

$$\text{Log (0.03)} - \text{log (0.01)} = - 1.52 - (- 2)$$

$$0.48$$

$$0.48$$

$$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O})$$

$$\text{Fe}_2\text{O}_3 = 6.79$$

$$\text{MgO} = 0.05$$

$$\text{Na}_2\text{O} = 0.01$$

$$\text{K}_2\text{O} = 0.03$$

$$\text{Log (Fe}_2\text{O}_3 + \text{MgO)} / (\text{Na}_2\text{O} + \text{K}_2\text{O}) = \text{log (6.79 + 0.05)} / (0.01 + 0.03)$$

$$\text{Log (6.84 / 0.04)} = \text{log (171)} = 2.23$$

Table 16: Classification of the Sandstone Samples from the Geochemical Result.

Sample	Log SiO ₂ / Al ₂ O ₃	Log (K ₂ O/Na ₂ O)	Log (Fe ₂ O ₃ + MgO) / (Na ₂ O + K ₂ O)	Interpretation
L ₁	1.07	0.4	1.75	Sub-greywacke
L ₂	0.31	0.9	1.14	Sub-greywacke
L ₃	1.08	0.7	1.54	Sub-greywacke
L ₄	0.9	0.63	1.87	Sub-greywacke
L ₅	0.93	0.53	1.77	Sub-greywacke
L ₆	0.28	0.96	1.27	Sub-greywacke
L ₇	0.84	0.75	1.25	Sub-greywacke
L ₈	1.04	0.53	1.64	Sub-greywacke
L ₉	1.06	0.48	2.23	Sub-greywacke

6. Conclusion

The presence of brownish red and purple coloration in the quartz shows the presence of hematite (Fe₂O₃) and they are typical of non- marine environment. Formations located in warm, humid climates often develop such coloration of quartz, showing that there is insufficient organic matter present to reduce the ferric iron to the relatively soluble ferrous state [10].

The presence of more than 15% of matrix in the rock samples shows is a greywacke and a greywacke is a high grade diagenetic or low grade metamorphic product.

The presence of larger clasts of quartz in the sandstone shows the sandstone is most likely deposited in high energy environments and is transported with lower energy making it have lesser impacts of weathering. They are characteristics of submarine fan, slope, and abyssal deposits. Detrital modes of sandstone also provide information about the tectonic settings of basins of deposition [11].

The relationship between sandstone petrography and tectonic setting has been studied by many authors

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